(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
21 June 2001 (21.06.2001)

PCT

(10) International Publication Number
WO 01/44533 A1

(51) International Patent Classification⁷: C23C 4/06, 4/08

(21) International Application Number: PCT/CA00/01455

(22) International Filing Date: 7 December 2000 (07.12.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/461,280 15 December 1999 (15.12.1999) US

(71) Applicant: PRATT & WHITNEY CANADA CORP. [CA/CA]; Astle, Jeffrey, W., Legal Services (01BE5), 1000 Marie Victorin, Longueuil, Québec J4G 1A1 (CA).

(72) Inventor: CHEUNG, Kin, L.; 9 Saddletree Drive, Toronto, Ontario M2H 3L1 (CA).

(74) Agent: ASTLE, Jeffrey, W.; Pratt & Whitney Canada Corp., Legal Dept. (01BE5), 1000 Marie Victorin, Longueuil, Québec J4G 1A1 (CA).

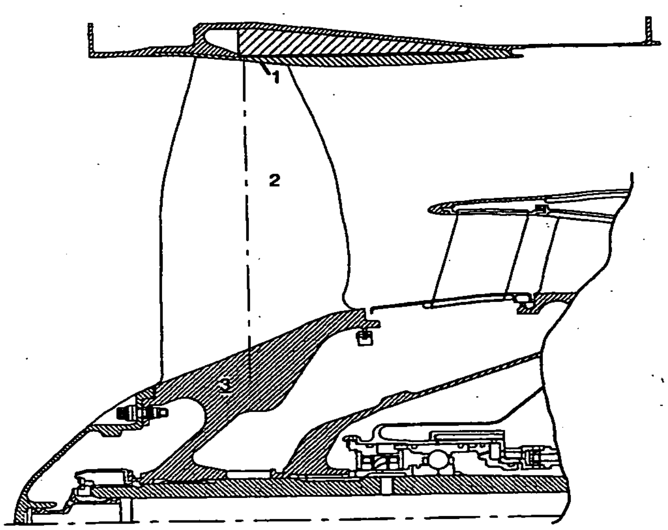
(81) Designated States (national): CA, JP, RU.

(84) Designated States (regional): European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

Published:
— *With international search report.*
— *Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: ABRADABLE COATINGS



(57) Abstract: The invention concerns low porosity thermally sprayed abradable clearance control coatings for use in gas turbine engines at elevated temperatures, for improved clearance control to turbine or compressor blade clearances and labyrinth seal clearance. The coatings includes from 5-90 % mica phase in a metal alloy matrix from 95-10 % by phase content. The metal alloy matrix used varies depending on the operating temperature of the engine component. Al-Si alloys are used for temperatures up to 800 °F; Al-Cu alloys up to 1200 °F; Ni-Cr-Fe-Mo-Co-W alloys up to 1800 °F where oxidation is less severe; and Co-Ni-Cr-Al-Y alloys up to 1800 °F where oxidation is severe and the higher relative cost is justified by their superior oxidation and corrosion resistance. Advantageously, the mica and metal alloy ingredient f the coating can be supplied to a thermal spray applicator in powder form via two separate and independently controlled gas streams and powder feed units.

WO 01/44533 A1

ABRADABLE COATINGS

TECHNICAL FIELD

The invention concerns low porosity thermally sprayed abradable clearance control coatings for use in gas turbine engines at elevated temperatures, for maintaining turbine or compressor blade clearances and labyrinth seal clearances. The coating microstructure ranges from 5-90% mica by phase volume in a metal alloy matrix ranging from 95-10% by phase volume, The mica phase provides good dry lubricity, thermal insulation, oxidation and chemical stability to the coating.

BACKGROUND OF THE ART

The efficiency of a gas turbine engine depends on adequate clearance control between stationary and rotating parts to minimise interstage gas leakage in compressor and turbine sections of the engine. Although engine components are manufactured to very precise tolerances, it is necessary to provide cold clearance to compensate for the expansion of metal under heat and stress during operation. A sufficient cold clearance is provided for example between the tips of rotating blades and the surrounding stationary casing assembly to accommodate centrifugal growth of rotating blade and disc components as well as differential thermal growth between the rotating and the stationary components. To maximise engine performance, cold clearances are set such that rubbing between adjacent components is experienced during the transient run-in condition, and consequently, requires a suitable abradable coating. It is conventional to provide an abradable rub strip in the stationary casing surrounding rotating blades and other rotating elements. The rotating blade tips penetrate the rub strip, usually coated with an abradable coating,

during initial run-in, thereby abrading the coating and permitting the blade tips to form a conformance seal with the rub strip at the casing assembly. Abradable coatings are also provided on the surfaces of labyrinth seal lands opposite the rotating knife edge seal teeth for similar purposes. The coating permits the rotating seal teeth under operating conditions to abrade and penetrate the coating to form a conformance seal, thus accommodating for thermal expansion and stress induced clearance changes.

Various types of abradables and abradable coating compositions have been conventionally used with varying degrees of success. For example United States Patent No. 3,879,831 to Rigney et al. concerns a nickel based high temperature sintered high porosity abradable which contains 35-37% porosity and 3-15% diatomaceous earth. This abradable material achieves abradability through use of high porosity, 35-37%, to reduce the amount of material which must be worn away during rubbing, so as to: increase ease of rotating element penetration, reduce wear of the rotating element, and reduce heat generation from rubbing friction. Such conventional abradable coatings have good thermal insulation characteristics, resulting from both the high porosity and the inclusion of diatomaceous earth, which helps to minimise the thermal distortion of stationary casings.

However, it has been found that porous abradable coatings have a distinct disadvantage in inducing increased seal leakage through voids in the abradable thereby causing a severe performance penalty. A further disadvantage of a homogeneous abradable coating is that microstructure uniformity through the coating thickness is a compromise between the need for good bond strength

adjacent to the work piece, good cohesive strength and erosion resistance within the coating, and good abradability at and adjacent the coating surface. Optimal coating abradability is not achieved with a homogeneous coating since optimal interface bonding strength, coating cohesive strength and erosion resistance, as well as optimal abradability are directly conflicting objectives.

Conventional abradable coatings operating up to 800°F generally incorporate an aluminium alloy matrix, which is soft relative to rotating seal elements for easier coating penetration, and for minimum wear to rotating elements. The aluminium alloy abradable coating is sacrificial, being preferentially abraded (worn out) to ensure a tight conformance seal between the rotating elements and its stationary casing at engine operating conditions. However, it has been found that rub debris from aluminium alloy coatings transfers to rotating blade tips and agglomerates into globules. These globules cut deep grooves into the coating as the blade rotates and induce severe performance losses from gas leakage and gas re-circulation through the deep grooves. As a result, abradable coatings that have no means to prevent rub debris transfer to blade tips are undesirable.

A conventional response to prevent rub debris transfer is to provide dry lubricity characteristics to the abradable coating. The improved dry lubricity lubricates the coating and blade tips during rubbing and prevents rub debris transfer. The dry lubrication properties of polyester, hexagonal boron nitride, or graphite are commonly deployed to make abradable coatings for such purpose. However, polyester is a relatively expensive material with marginal dry lubricity which

fails to prevent rub debris transfer. Graphite within the abradable coating provides good dry lubricity and prevents rub debris transfer, however, graphite has a large galvanic potential difference relative to the aluminium alloy matrix in the coating. Thus graphite in the abradable coating induces galvanic corrosion within the coating in the presence of moisture in the atmosphere, i.e. under humid conditions. The galvanic corrosion causes swelling and spalling of the abradable coating, and is thus detrimental to engine performance. Besides, graphite is moderately toxic if inhaled, graphite creates environmental difficulties during manufacture, and protective measures for workers must be taken. In addition, graphite, being a thermal conductor, helps conduct heat from hot gas path to stationary casing, which can increase thermal distortion of the casing thus compromising sealing efficiency. It is an object of the invention to provide abradable coatings with superior dry lubricity and thermal insulation characteristics, which do not suffer from the disadvantage of galvanic corrosion as in conventional graphite-aluminium alloy coatings.

It is an object of the present invention to provide low porosity abradable clearance control coatings to eliminate the disadvantages of the prior art such as gas leakage paths from pores in conventional porous abradable or from rub debris transfer due to poor dry lubricity, which induce severe losses in engine efficiency.

It is a further object of the invention to utilise relatively inexpensive thermal spray coating processes to produce abradable clearance control coatings with graded compositions and coating microstructure to optimise abradable performance by providing coatings with improved

bond strength to the work piece, improved cohesive strength and erosion resistance within the coating, as well as optimum abradable properties in the coating rub zone.

Further objects of the invention will be apparent from review of the disclosure and description of the invention below.

DISCLOSURE OF THE INVENTION

The invention concerns low porosity thermally sprayed abradable clearance control coatings for use in gas turbine engines at elevated temperatures, for improved clearance control to turbine or compressor blade clearances and labyrinth seal clearances. The coatings have microstructures ranging from 5-90% mica phase by phase volume in a metal alloy matrix ranging from 95-10% by phase volume.

The high mica phase content in the coating provides good dry lubricity and thermal insulation. Dry lubricity in the coating inhibits the transfer and agglomeration of rub debris onto blade tips. Conventional use of graphite for dry lubricity has resulted in galvanic corrosion with aluminium alloy matrix under humid conditions. Mica however is chemically inert and is a good electrical insulator. Mica does not induce galvanic corrosion with aluminium alloys or other metal alloys. Mica is readily available, and is inexpensive compared to conventionally used dry lubricants, such as polyester, hexagonal boron nitride, or graphite.

The metal alloy matrix selected for the abradable varies depending on the operating temperature of the engine components. Al-Si alloys are preferred for

temperatures up to 800°F; Al-Cu alloys for temperatures up to 1200°F; Ni-Cr-Fe-Mo-Co-W alloys for temperatures up to 1800°F where oxidation is less severe; and Co-Ni-Cr-Al-Y alloys for temperatures up to 1800°F where a higher relative cost is justified by the alloys' superior oxidation and corrosion resistance.

Advantageously, the mica and metal alloy ingredients for the coatings can be supplied to a thermal spray applicator in powder form via two separate and independently controlled gas streams and powder feed units. The separate gas streams and powder feeds enable deposition of a coating with graded coating microstructure (phase volume content). Higher metal alloy matrix phase content adjacent the work piece-coating interface optimises bond strength to the work piece and improves cohesive strength as well as erosion resistance within the coating. Higher mica phase content adjacent the exposed coating surface optimises coating dry lubricity and abradability, thus improving engine performance.

Industrial use of mica has conventionally been for electrical insulation, thermal insulation, or flame resistance applications for its excellent thermal insulation and electrical insulation properties as well as for its high thermal stability temperature. Mica has also been commonly used as filler for plastics and paints for improved thermal resistance and ultra violet radiation resistance.

The inventor has recognised that mica also has excellent dry lubricity properties, which together with its thermal and chemical stability, electrical and thermal insulation properties, low hardness, natural

abundance and low cost, makes it suitable as a dry lubricant to be incorporated into abradable coatings.

Mica has a sheet or plate-like structure consisting of sheet layers of strongly bonded silica tetrahedra with a weak ionic bond joining the sheets. The inventor has recognised that mica cleaves readily at its basal plane and as a result has excellent dry lubricity which prevents transfer of rub debris onto blade tips. Mica is relatively soft compared to the metal alloys used in gas turbine engines. Therefore rotating components will not wear when rubbed against a relatively softer coating high in mica phase content.

Unlike graphite, mica is chemically inert and is a good electrical insulator, thus mica does not induce galvanic corrosion with aluminium alloy matrix under humid condition.

In addition, mica is inexpensive, it is more than one hundred times less expensive relative to polyester or hexagonal boron nitride, which are commonly used dry lubricants for abradable coatings.

Labyrinth seal lands in high temperature service areas of turbine engines are generally brazed nickel alloy honeycombs which are expensive to manufacture and costly to refurbish during engine overhaul relative to thermal spray coatings. In addition, voids in honeycomb seals induce increased seal leakage and cause severe engine performance penalties. Thus low porosity thermal spray abradable coatings with no voids to create leakage path are much more desirable for improved performance as well as for their lower manufacturing and refurbishment costs.

The invention includes a gas turbine engine with the above described abradable coatings applied to various components of the engine thus forming abradable layers about fan blades, axial compressor blades, centrifugal compressor impellers, turbine blades, and abradable layers on running seal landings.

DESCRIPTION OF THE DRAWING

In order that the invention may be readily understood, one application of the invention is illustrated by way of example in the accompanying drawing.

Figure 1 is an axial cross-sectional view through the upper half of a fan rotor and fan case of a gas turbine engine, showing the abradable coating applied to the internal surface of the fan case to minimise fan tip clearance in operation.

Further details of the invention and its advantages will be apparent from the detailed description included below.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The invention concerns thermally sprayed abradable clearance control coatings for application to stationary components of turbine engines. The invention includes coatings ranging from 5-90% in mica phase volume content within a metal alloy matrix ranging from 95-10% in phase volume content.

The metal alloy matrix is chosen based on its temperature and environmental limitations as well as on its compatibility to the mating engine components considering relative hardness, chemical reactivity, thermal expansion etc. The coatings are produced by

thermal spray processes where the coating constituents in powder form are metered into compressed gas streams which suspends and delivers the powders to the flame where they are heated to a molten or semi-molten state and propelled to the work piece at high speeds and splatter cooled to form a bond onto the work piece upon impact. The preferred thermal spray processes are plasma spray, flame spray, high velocity oxy-fuel spray (HVOF), detonation-gun spray, or any high energy variations of such processes. The abradable coatings may be deposited in air or inside a controlled environment chamber under: vacuum, low vacuum, or low pressure with a substitute atmosphere. These known processes are used to produce homogenous or non-homogeneous low porosity coatings which typically have 1-10% porosity levels. Depending on the service temperature, oxidation or corrosion resistance characteristics desired, the metal alloy matrix of the coating is preferably selected from: Al-Si alloys for service temperature up to 800°F; Al-Cu alloys for service temperature up to 1200°F; Ni-Cr-Fe-Mo-Co-W alloys for service temperature up to 1800°F; and Co-Ni-Cr-Al-Y alloys for service temperature up to 1800°F where oxidation and corrosion resistance are more critical.

In most applications for use in gas turbine engines, the preferred coating microstructure ranges from 40-80% metal alloy matrix and 20-60% phlogopite mica for good abradability and coating strength. However, of advantage in many applications is the capability to supply thermal spray coatings with graded coating microstructure (graded phase content). Coatings with graded microstructure are produced by metering the supply of mica powder and metal alloy powder to the thermal spray unit via two separate and independently controlled

gas streams and powder feed units. The separate and independently controlled gas streams and powder feeds enable deposition of coatings with graded phase content to customise the coating properties at different coating thickness levels to suit the particular environment, abradability, strength, and erosion characteristics desired. Coating to work piece interface bond strength, and coating cohesive strength as well as erosion resistance are increased as the metal alloy matrix phase volume is increased. Whereas a high mica phase content adjacent the exposed coating surface optimises coating abradability through increased dry lubricity which prevents rub debris transfer, reduced coating hardness which improves penetration by rotating seal elements as well as reduced seal element wear from rubbing with reduced coating hardness. A preferred graded abradable coating is one where the proportion of metal alloy phase to mica phase is relatively higher adjacent the work piece to coating interface for optimum bond strength, but lower adjacent the coating surface for optimum abradability. Examples of grading ranges are where: the phase content by volume adjacent the work piece is 0.01-20% mica and 80-99.99% metal alloy, whereas adjacent the coating surface is 10-30% mica and 70-90% metal alloy; or 30-50% mica and 50-70% metal alloy, or 50-70% mica and 30-50% metal alloy, or 70-90% mica and 10-30% metal alloy; or where the phase content by volume adjacent the work piece is 20-30% mica and 70-80% metal alloy, whereas adjacent the coating surface is 30-50% mica and 50-70% metal alloy, or 50-70% mica and 30-50% metal alloy, or 70-90% mica and 10-30% metal alloy; or where the phase content by volume adjacent the work piece is 30-40% mica and 60-70% metal alloy, whereas adjacent the coating surface is 30-50% mica and

50-70% metal alloy, or 50-70% mica and 30-50% metal alloy, or 70-90% mica and 10-30% metal alloy; or where the phase content by volume adjacent the work piece is 40-55% mica and 45-60% metal alloy, whereas adjacent the coating surface is 45-60% mica and 40-55% metal alloy, or 60-90% mica and 10-40% metal alloy. The metal alloy matrix and the phase ranges selected adjacent the work piece-coating interface and adjacent coating surface depends on the operation environment such as temperature, pressure, oxidation and corrosion potential, and the type of alloys used in the rotating and stationary components.

The mica may be selected from synthetic mica, or any naturally occurring mica such as phlogopite; muscovite; fuchite; roscolite; and margarite. Phlogopite mica is preferred where high temperature stability is desired, however, muscovite is generally less expensive and may be adequate for lower temperature service up to 1100°F.

Where the coating service temperature is up to 800°F the preferred metal alloy matrix is an Al-Si alloy with 11-13% Si by weight: 0-0.80% Fe; 0-0.30% Cu; 0-0.20% Zn, 0-0.15% Mn; and 0-0.10%Mg, with the balance being Al. This composition is suitable for producing abradable coatings for compressor seals, and labyrinth seals.

Where the coating service temperature is up to 1200°F the preferred metal alloy matrix is an Al-Cu alloy (or aluminium bronze) with 9-11% Al by weight, 0-1.50% Fe, and the balance Cu. The nominal 10% Al-90% Cu alloy provides a relatively soft matrix for easy penetration and with little or no wear to the rotating components. The higher temperature capability of an Al-Cu alloy makes it suitable for use as impeller abradable coating in high

pressure compressor and for use as labyrinth seal land abradable coating in low pressure turbines.

Where the coating service temperature is up to 1800°F the preferred metal alloy matrix is a relatively inexpensive Ni-Cr-Fe-Mo-Co-W alloy with 20-23% Cr, 17-20 % Fe, and 8-10% Mo, 0.5-2.5% Co, and 0.2-1.0% W by weight, and 0.05-0.15% C; 0-1.00% Si; 0-1.00 Mn; 0-0.008% B; 0-0.15% Ti; 0-0.50% Al; 0-0.50% Cu; 0-0.040% P; and 0-0.030% S, with the balance Ni. This alloy has higher temperature capability than aluminium bronze with improved resistance to oxidation, corrosion and erosion at temperature above 1200° F. Ni-Cr-Fe-Mo-Co-W alloy is suitable for use as abradable for labyrinth seal land in high pressure turbine and low pressure turbine areas where the environment for oxidation is less severe relative to high pressure turbine outer seal areas. The lower manufacturing and refurbishment cost of thermal spray coatings relative to brazed honeycomb seals makes coatings advantageous as a replacement for conventional brazed honeycomb labyrinth seal lands in gas turbine engines.

Where the coating service temperature is up to 1800°F and superior oxidation and corrosion resistance is desired, the preferred metal alloy matrix is a Co-Ni-Cr-Al-Y alloy with 31-33% Ni, 20-22% Cr, 7-9% Al, and 0.35-0.65% Y, 0-0.03% C; 0-0.01% P; 0-0.01% S; 0-0.04% O; 0-0.01% N; 0-0.005% H by weight; and balance Co. This Co-Ni-Cr-Al-Y alloy is better suited for high-pressure turbine outer seals where the environment for oxidation is severe and the higher cost is justified.

Figure 1 shows an example application of the abradable coating 1 applied to the internal surface of

the fan case to minimise clearance in operation between the tips of the fan blades 2 mounted on the fan hub 3.

The above described abradable coatings can be advantageously applied to many components of the engine to minimise clearance with rotating members thus forming abradable layers about fan blades, axial compressor blades, centrifugal compressor impeller blades, turbine blades, and abradable layers on running seal landings.

Although the above description relates to a specific preferred embodiment as presently contemplated by the inventor, it will be understood that the invention in its broad aspect includes other metal alloys as the coating matrix which are selected to more suitably match required engine operation conditions such as temperature and atmospheric conditions, as well as compatibility to materials of mating engine components such as: hardness, galvanic potential, thermal expansion coefficient etc.

I CLAIM:

1. A thermally sprayed abradable clearance control coating for application to a work-piece, the coating comprising from 5-90% mica phase in a metal alloy matrix ranging from 95-10% by phase volume, wherein the matrix comprises a composition selected from the group consisting of: Al-Si alloy; Al-Cu alloy; Ni-Cr-Fe-Mo-Co-W alloy; and Co-Ni-Cr-Al-Y alloy.

2. An abradable coating in accordance with claim 1 comprising by phase volume 70-90% Al-Si alloy and 10-30% muscovite mica.

3. An abradable coating in accordance with claim 1 wherein the Al-Si alloy comprises Al with 11-13% Si by weight.

4. An abradable coating in accordance with claim 3 wherein the Al-Si alloy comprises by weight: 0-0.80% Fe; 0-0.30% Cu; 0-0.20% Zn; 0-0.15% Mn; and 0-0.10%Mg.

5. An abradable coating in accordance with claim 1 comprising by phase volume 45-70% Al-Si alloy and 30-55% muscovite mica.

6. An abradable coating in accordance with claim 1 comprising by phase volume 70-90% Al-Cu alloy and 10-30% phlogopite mica.

7. An abradable coating in accordance with claim 1 wherein the Al-Cu alloy comprises Cu with 9-11% Al by weight.

8. An abradable coating in accordance with claim 7 wherein the Al-Cu alloy comprises by weight 0-1.50% Fe.

9. An abradable coating in accordance with claim 1 comprising by phase volume 45-70% Al-Cu alloy and 30-55% phlogopite mica.

10. An abradable coating in accordance with claim 1 comprising by phase volume 70-90% Ni-Cr-Fe-Mo-Co-W alloy and 10-30% phlogopite mica.

11. An abradable coating in accordance with claim 1 wherein the Ni-Cr-Fe-Mo-Co-W alloy comprises Ni with 20-23% Cr, 17-20 & Fe, 8-10% Mo, 0.5-2.5%Co and 0.2-1.0% W by weight.

12. An abradable coating in accordance with claim 11 wherein the Ni-Cr-Fe-Mo-Co-W alloy comprises by weight 0.05-0.15% C; 0-1.00% Si; 0-1.00 Mn; 0-0.008% B; 0-0.15% Ti; 0-0.50% Al; 0-0.50% Cu; 0-0.040% P; and 0-0.030% S.

13. An abradable coating in accordance with claim 1 comprising by phase volume 45-70% Ni-Cr-Fe-Mo-Co-W alloy and 30-55% phlogopite mica.

14. An abradable coating in accordance with claim 1 comprising by phase volume 70-90% Co-Ni-Cr-Al-Y alloy and 10-30% phlogopite mica.

15. An abradable coating in accordance with claim 1 wherein the Co-Ni-Cr-Al-Y alloy comprises cobalt with 31-33% Ni, 20-22% Cr, 7-9% Al, and 0.35-0.65% Y by weight.

16. An abradable coating in accordance with claim 15 wherein the Co-Ni-Cr-Al-Y alloy comprises by weight 0-0.03% C; 0-0.01% P; 0-0.01% S; 0-0.04% O; 0-0.01% N; and 0-0.005% H.

17. An abradable coating in accordance with claim 1 comprising by phase volume 45-70% Co-Ni-Cr-Al-Y alloy and 30-55% phlogopite mica.

18. An abradable coating in accordance with claim 1 wherein the mica is selected from the group consisting of: synthetic mica; phlogopite; muscovite; fuchite; roscolite; and margarite.

19. An abradable coating in accordance with claim 1 with a graded coating microstructure and composition where the metal alloy phase volume varies between a first portion adjacent an interface between the work piece and the coating, and second portion adjacent an exposed coating surface, wherein the proportion of metal alloy phase volume to mica phase volume is higher adjacent the work piece-coating interface than adjacent the coating surface.

20. An abradable coating in accordance with claim 19 wherein the phase content by volume adjacent the work piece-coating interface is 0.01-20% mica and 80-99.99% metal alloy, and adjacent the coating surface is 10-30% mica and 70-90% metal alloy.

21. An abradable coating in accordance with claim 19 wherein the phase content by volume adjacent the work piece-coating interface is 0.01-20% mica and 80-99.99% metal alloy, and adjacent the coating surface is 30-50% mica and 50-70% metal alloy.

22. An abradable coating in accordance with claim 19 wherein the phase content by volume adjacent the work piece-coating interface is 0.01-20% mica and 80-99.99% metal alloy, and adjacent the coating surface is 50-70% mica and 30-50% metal alloy.

23. An abradable coating in accordance with claim 19 wherein the phase content by volume adjacent the work piece-coating interface is 0.01-20% mica and 80-99.99% metal alloy, and adjacent the coating surface is 70-90% mica and 10-30% metal alloy.

24. An abradable coating in accordance with claim 19 wherein the phase content by volume adjacent the work piece-coating interface is 20-30% mica and 70-80% metal alloy, and adjacent the coating surface is 30-50% mica and 50-70% metal alloy.

25. An abradable coating in accordance with claim 19 wherein the phase content by volume adjacent the work piece-coating interface is 20-30% mica and 70-80% metal alloy, and adjacent the coating surface is 50-70% mica and 30-50% metal alloy.

26. An abradable coating in accordance with claim 19 wherein the phase content by volume adjacent the work piece-coating interface is 20-30% mica and 70-80% metal alloy, and adjacent the coating surface is 70-90% mica and 10-30% metal alloy.

27. An abradable coating in accordance with claim 19 wherein the phase content by volume adjacent the work piece-coating interface is 30-40% mica and 60-70% metal alloy, and adjacent the coating surface is 30-50% mica and 50-70% metal alloy.

28. An abradable coating in accordance with claim 19 wherein the phase content by volume adjacent the work piece-coating interface is 30-40% mica and 60-70% metal alloy, and adjacent the coating surface is 50-70% mica and 30-50% metal alloy.

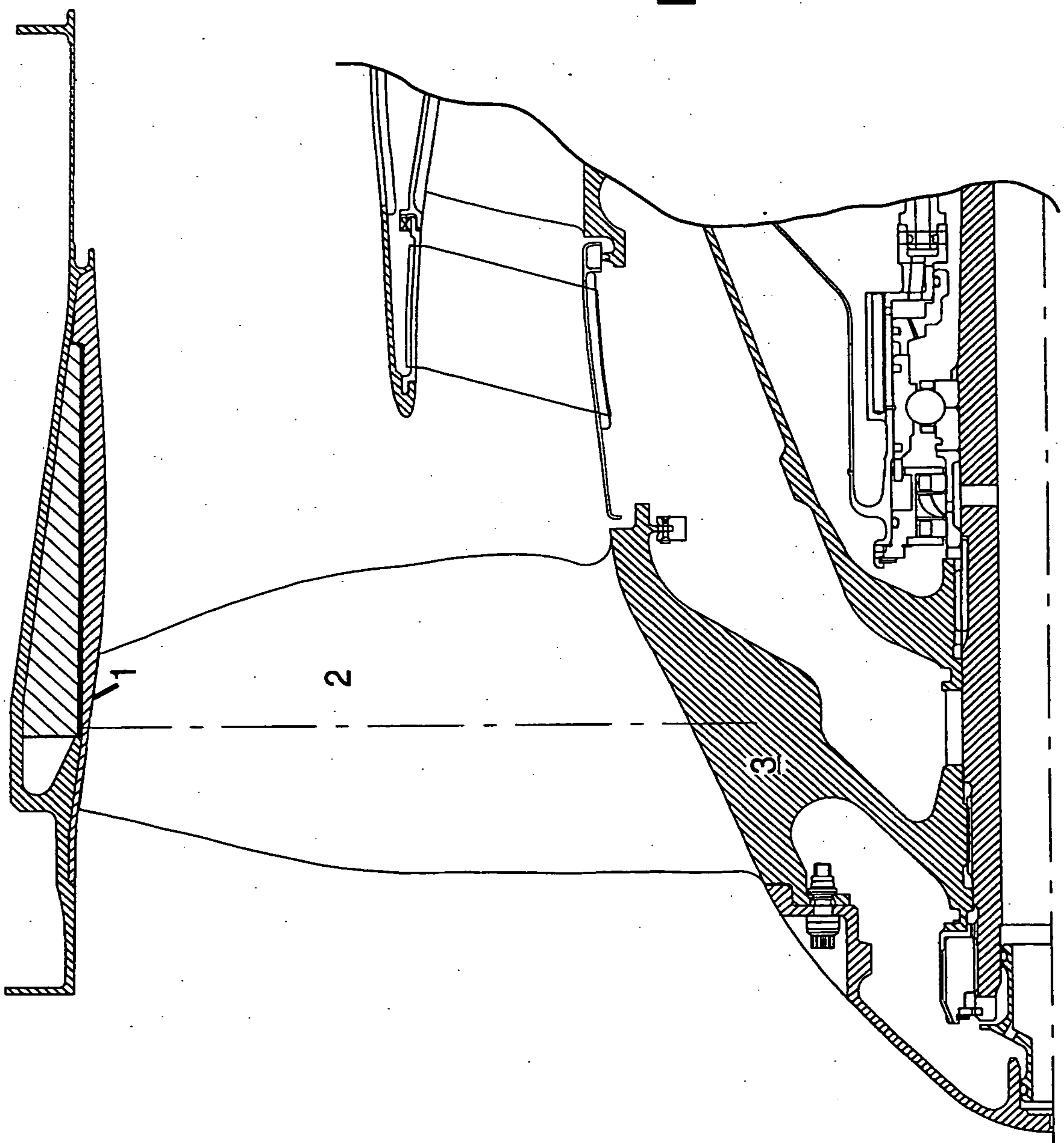
29. An abradable coating in accordance with claim 19 wherein the phase content by volume adjacent the work piece-coating interface is 30-40% mica and 60-70% metal alloy, and adjacent the coating surface is 70-90% mica and 10-30% metal alloy.

30. An abradable coating in accordance with claim 19 wherein the phase content by volume adjacent the work piece-coating interface is 40-55% mica and 45-60% metal alloy, and adjacent the coating surface is 45-60% mica and 40-55% metal alloy.

31. An abradable coating in accordance with claim 19 wherein the phase content by volume adjacent the work piece-coating interface is 40-55% mica and 45-60% metal alloy, and adjacent the coating surface is 60-90% mica and 10-40% metal alloy.

32. A gas turbine engine including a thermally sprayed abradable clearance control coating applied to an engine component, the coating comprising from 5-90% mica phase in a metal alloy matrix ranging from 95-10% by phase volume, wherein the matrix comprises a composition selected from the group consisting of: Al-Si alloy; Al-Cu alloy; Ni-Cr-Fe-Mo-Co-W alloy; and Co-Ni-Cr-Al-Y alloy, wherein said component is selected from the group comprising: a fan case; axial compressor rotor shroud; centrifugal compressor impeller shroud; turbine rotor shroud; and a running seal landing.

FIG.1



INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 00/01455

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C23C4/06 C23C4/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 C23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 976 695 A (HAJMRLE KAREL ET AL) 2 November 1999 (1999-11-02) column 1, line 14-18 claim 3; example 2	1,32
X	US 3 879 831 A (RIGNEY DAVID V ET AL) 29 April 1975 (1975-04-29) column 1, line 12-15; claim 1	1,10-17, 32
X	US 3 147 087 A (ALFRED EISENLOHR) 1 September 1964 (1964-09-01) examples 1,3	1,32

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 April 2001	17/04/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Anna, P

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter. ..onal Application No
PCT/CA 00/01455

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5976695 A	02-11-1999	AU 3993397 A	09-04-1998
		CA 2216068 A	02-04-1998
		FR 2753992 A	03-04-1998
		GB 2317899 A,B	08-04-1998
US 3879831 A	29-04-1975	DE 2239840 A	24-05-1973
		FR 2160358 A	29-06-1973
		GB 1403211 A	28-08-1975
		JP 1099246 C	18-06-1982
		JP 48057804 A	14-08-1973
		JP 56044122 B	17-10-1981
US 3147087 A	01-09-1964	NONE	